Rendiconti online Soc. Geol. It., Vol. 5 (2009), 48-50, 2 ff.

Geometric and Kinematic modeling of the thrust fronts in the Montello-Cansiglio area from geologic and geodetic data (Eastern Southalpine Chain, NE Italy).

PIERFRANCESCO BURRATO (*), PAOLO MARCO DE MARTINI (*), MARIA ELIANA POLI (°) & ADRIANO ZANFERRARI (°)

RIASSUNTO

Modellizzazione geometrica a cinematica da dati geologici e geodetici delle strutture compressive nell'area Montello-Cansiglio (Catena Sudalpina Orientale, Italia nord-orientale).

Questo lavoro è dedicato allo studio delle geometrie e dei ratei di deformazione di breve e medio termine delle strutture compressive attive facenti parte dei fronti esterni della Catena Sudalpina, nel settore dell'anticlinale del Montello. Il metodo adottato utilizza informazioni derivate dall'analisi di una linea geodetica di primo ordine dell'IGM, combinate con osservazioni geofisiche, geologiche e geomorfologiche di superficie e di sottosuolo. La linea geodetica presa in esame mostra lungo alcuni suoi segmenti dei movimenti verticali relativi, positivi rispetto ai segmenti adiacenti (maggiori sollevamenti). Questi segnali geodetici, ottenuti dal confronto delle quote dei capisaldi misurate durante due distinte campagne separate da un intervallo di tempo di circa 50 anni, avvengono in corripondenza dell'attraversamento di faglie cieche e sono stati quindi interpretati come dovuti all'attività di queste strutture sepolte. Per l'interpretazione, è stata costruita una sezione geologica che segue la traccia della linea di livellazione, ed è stato quindi modelizzato il segnale geodetico adottando un metodo diretto. Nel modello, le geometrie di partenza delle faglie sono state prese dalla sezione geologica, e sono state poi modificate per riprodurre il segnale geodetico. Una volta fissate le geometrie delle faglie, gli *uplift rate* sono stati convertiti in *slip* e *shortening rate* e comparati con: 1- i ratei di medio e lungo termine derivati dalle osservazioni geologiche e geomorfologiche per evidenziare eventuali cambiamenti nel tempo; e 2- con i tassi di convergenza GPS per studiare la partizione delle deformazione tra i diversi fronti. Infine sono state usate relazioni analitiche ed empiriche per stimare la massima magnitudo e i tempi di ricorrenza dei potenziali futuri terremoti.

Key words*: Montello anticline, slip rates, Eastern Southalpine Chain, NE Italy.*

INTRODUCTION

We present a study of the external thrust fronts of the Eastern Southalpine Chain (ESC) in the Montello-Cansiglio area (Fig. 1) using a combination of surface and subsurface geologic, morphotectonic and geodetic data. The aim of this work is to constrain the geometry of the active thrusts and to compute the corresponding rates of deformation. In addition we present an evaluation of the seismic potential of the seismogenic sources estimating the maximum magnitude of the potential earthquakes associated to the individual structures and their recurrence interval.

The active tectonics of the study area is the result of the relative motion of Africa and its northern Adriatic promontory with respect to Europe (e.g. CASTELLARIN, 2004). The analysis of the GPS velocities predicts a counter clockwise motion of the Adriatic block around a pole located in the western Alps (e.g. SERPELLONI *et alii*, 2005). This motion produces increasing convergence from west to east, which is matched by a similar increase of the seismic moment release. According to this model, in the Veneto Region N–S to NNW–SSE convergence is inferred to be in the order of about 1,5 mm/a (e.g. D'AGOSTINO *et alii*, 2005; GRENERCZY *et alii*, 2005).

The Neogene-Quaternary ESC is part of the S-verging

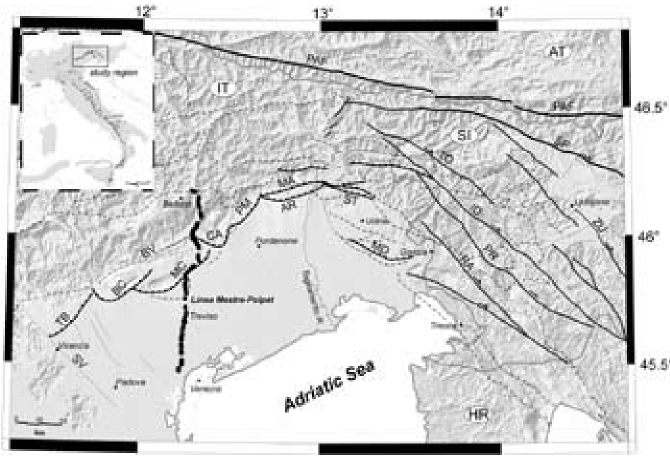

Fig. 1 – Regional tectonic sketch of northeastern Italy and western Slovenia. The black dots highlight the trace of the leveling line used in this work (from BURRATO *et alii*, 2008, modified).

backthrust chain of the Alps. West of the Tagliamento River, the ESC structures follow a WSW-ENE trend, and the activity of the main thrust fronts steadily migrated southwards (DOGLIONI, 1992; CASTELLARIN & CANTELLI, 2000). The more external contractional structures are the Bassano–Valdobbiadene Thrust (BV Thrust in Fig. 1), associated with the uplift of the mountain front (DOGLIONI, 1992), and in a

(*) Istituto Nazionale di Geofisica e Vulcanologia, Sezione Sismologia e Tettonofisica, Roma

(°) Dipartimento di Georisorse e Territorio, Università di Udine

more external position, a system of growing mainly blind thrusts running at the boundary between the Prealpine relief and the plain areas (Fig. 1). This system is composed of several fault segments identified by Galadini *et alii* (2005), which produce the uplift of Neogene–Quaternary deposits and along its eastern portion border the mountain front of the Carnian Prealps. The Montello-Conegliano Thrust (MC Thrust in Fig. 1) is the leading thrust of the ESC in the study sector. Its activity is expressed by the uplift and warping of Upper Miocene and Upper Pliocene Pleistocene deposits, forming the exposed Montello anticline (Ferrarese *et alii*, 1998; Benedetti *et alii*, 2000; Fantoni *et alii*, 2001; Fantoni *et alii*, 2002) one of the most impressive folds emerging from the Venetian and Friulian Plain. Surface and subsurface geological, geophysical and structural data show that the MC Thrust is a 35 km long fault that dies out to the east where it is overridden by the neighbouring Cansiglio Thrust (CA Thrust; Galadini *et alii*, 2005). To the west the MC Thrust has a right-stepping en-echelon relationship with the adjoining Bassano-Cornuda Thrust (BC Thrust in Fig. 1). To the north of the MC Thrust the eastern portion of the BV Thrust is found at the base of the mountain front (Fig. 1). The area comprised between the two thrust fronts is characterized by the presence of a triangle zone formed by the BV Thrust and by a back-thrust splaying-off the MC Thrust.

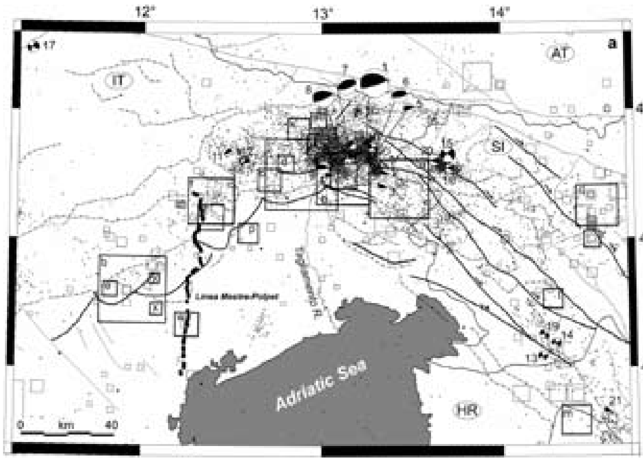

Fig. 2 – Map of historical and instrumental seismicity from the CPTI04 Catalogue (CPTI Working Group, 2004) and the 1977–2001 OGS Annual Bulletin (available from: http://www.crs.inogs.it/). (from Burrato *et alii*, 2008, modified).

The recent activity of the MC Thrust is testified by several Middle and Upper Pleistocene warped terraces of the Piave River paleo-course flanking the western termination of the fold (e.g. Benedetti *et alii*, 2000 and references threin), and by the eastward deflection of the Piave River around the growing anticline. Conversely, evidence of recent activity of the BV Thrust are more sparse and not conclusive (Galadini *et alii*, 2001). To the east, Late Quaternary activity of the CA Thrust is shown by morphotectonic evidence and folding and faulting of LGM slope deposits (Galadini *et alii*, 2005).

Ongoing seismic activity of the ESC results in several destructive M 6+ earthquakes that have been positively associated to individual segments of the external thrust fronts (Basili *et alii*, 2008; Burrato *et alii*, 2008; DISS Working Group, 2007; Galadini *et alii*, 2005). In addition, shallower M 5–6 events generated by smaller secondary structures pose a not negligible hazard to the region at a more local scale. In this contest, the almost continuous seismogenic belt that follows the most external ESC thrust front from the Tagliamento River (epicentral area of the Mmax 6.3 1976 seismic sequence) westward to Bassano (epicentral area of the Mw 6.6 1695 earthquake) is interrupted in the area of the Montello anticline (CPTI Working Group, 2004), with no earthquakes during the last 700 years (considered the interval of completness of the catalogue for events of M 6+) (Fig. 2).

METHOD

Our analysis focalized along the trace of the high precision IGM geodetic levelling line "Mestre-Polpet" that runs in a N-S direction from the plain near Venice to the inner sector of the Venetian Prealps near Belluno, and crosses both the MC-CA and BV thrust fronts (Fig. 1). We analyzed relative elevation changes measured by the geodetic line in a 50 years long time interval, referring them to the first nodal benchmark of the line considered as having a stable elevation (see D'Anastasio *et alii*, 2006 for an explanation of the method).

This study highlighted the occurrence of some segments of the line characterized by positive vertical relative motions with respect to nearby segments. These vertical movements, occurring at the crossing of the ESC thrust fronts, are local signals with a wavelength up to several kilometers superposed to a regional uplift trend. One of these sectors was already studied and linked to the active growing of the Montello anticline (De Martini *et alii*, 1998). In this study, we adopted a forward modeling procedure for the local geodetic uplift signals to estimate the thrusts recent activity.

To reconstruct the starting geometry of our model we used available seismic exploration data combined with surface geologic and morphotectonic observations, and produced a detailed geologic section along the trace of the leveling line. The geometric parameters of the thrust derived from this section (i.e. strike, angle of dip, depth) were used as input parameters for the modeling of their expected vertical surface dislocation. The results of the modeling were compared to the registration of the geodetic line to derive range values of the principal geometrical fault parameters.

Once the geometry of the active thrust faults were known, we converted the short-term uplift rates obtained from the analysis of the geodetic line into slip and shortening rates. Then, we compared them with: 1- the long- and mid-term geologic/geomorphic slip rates to check for variations through time; and 2- to the GPS shortening budget in order to examin the partitioning of the deformation across the different ESC thrust fronts.

Finally, since the area we studied is a seismic gap (Fig. 2) we also used analytical (e.g. Hanks & Kanamori, 1979) and empirical (e.g. Wells & Coppersmith, 1994) relationships to figure out maximum magnitude and recurrence interval of possible future earthquakes.

REFERENCES

BASILI R., VALENSISE G., VANNOLI P., BURRATO P., FRACASSI U., MARIANO S., TIBERTI M.M. & BOSCHI E. (2008) - *The Database of Individual Seismogenic Sources (DISS), version 3: summarizing 20 years of research on Italy's earthquake geology*. Tectonophysics, **453,** 20–43, doi:10.1016/j.tecto.2007.04.014.

BENEDETTI L., TAPPONNIER P., KING G.C.P., MEYER B. & MANIGHETTI I. (2000) - *Growth folding and active thrusting in the Montello region, Veneto, northern Italy*. J. Geophys. Res., **105**, 739-766.

BURRATO P., POLI M.E., VANNOLI P., ZANFERRARI A., BASILI R. & GALADINI F. (2008) - *Sources of Mw 5+ earthquakes in northeastern Italy and western Slovenia: An updated view based on geological and seismological evidence*. Tectonophysics, **453**, 157-176, doi: 10.1016/j.tecto. 2007.07.009.

CASTELLARIN A. (2004) - *Structural synthesis of the Eastern Alps: a collisional orogenic chain*. In: Wezel, F.C. (Ed.), Geology of Italy. Special Issue for the 32nd IGC. Episodes, **26** (3), 3–13.

CASTELLARIN A. & CANTELLI L. (2000) - *Neo-Alpine evolution of the Southern Eastern Alps*. J. Geodyn., **30**, 251–274.

CPTI WORKING GROUP (2004) - *Catalogo Parametrico dei Terremoti Italiani, v. 2004 (CPTI04)*. INGV, Bologna. Available at: http://emidius.mi.ingv.it/CPTI/.

D'AGOSTINO N., CHELONI D., MANTENUTO S., SELVAGGI G., MICHELINI A. & ZULIANI, D. (2005) - *Strain accumulation in the southern Alps (NE Italy) and deformation at the northeastern boundary of Adria observed by CGPS measurements*. Geophys. Res. Lett., **32** (19), doi:10.1029/2005GL024266.

D'ANASTASIO E., DE MARTINI P.M., SELVAGGI G., PANTOSTI D., MARCHIONI A. & MASEROLI A. (2006) - *Short-term vertical velocity field in the Apennines (Italy) revealed by geodetic levelling data*. Tectonophysics **418**, 219–234, doi:10.1016/j.tecto.2006.02.008.

DE MARTINI P.M., BURRATO P. & VALENSISE, G. (1998) - *Active tectonic structures in the Padana Plain: new discrimination strategy from a joint study of geomorphic and geodetic leveling data*. EGS annual meeting, Nice, April 1998 (abstract).

DISS WORKING GROUP (2007) - *Database of Individual Seismogenic Sources (version 3.0.4): A compilation of potential sources for earthquakes larger than M 5.5 in Italy and surrounding areas*. Available at: http://www.ingv.it/DISS.

DOGLIONI C. (1992) - *The Venetian Alps thrust belt*. In: McKlay, K.R. (Ed.), Thrust tectonics. Chapman and Hall, London, 319–324.

FANTONI R., BARBIERI C., CATELLANI D., CASTELLARIN D., DI GIULIO A. & PESSINA C. (2001) - *The record of south-Alpine events in the Venetian foreland and foredeep.* Geol. -Paläontol. Mitt. Innsbruck, **25**, 79–81.

FANTONI R., CATELLANI D., MERLINI S., ROGLEDI S. & VENTURINI S. (2002) – *La registrazione degli eventi deformativi cenozoici nell'avampaese veneto-friulano.* Mem. Soc. Geol. It., **57**, 301–313.

FERRARESE F., SAURO U. & TONELLO C. (1998) - *The Montello Plateau. Karst evolution of an alpine neotectonic morphostructure*. Zeit. für Geomorph., N.F. Suppl.-Bd. **109**, 41–62.

GALADINI F., MELETTI C. & VITTORI E. (2001) - *Major active faults in Italy: available surficial data*. Geol. En Mijn. (Netherlands Journal of Geosciences), **80**, 273-296.

GALADINI F., POLI M.E. & ZANFERRARI A. (2005) - *Seismogenic sources potentially responsible for earthquakes with M≥6 in the eastern Southern Alps (Thiene–Udine sector, NE Italy)*. Geophys. J. Int., **161**, 739–762. doi:10.1111/j.1365-246X.2005.02571.x.

GRENERCZY, G., SELLA G., STEIN S. & KENYERES, A. (2005) - *Tectonic implications of the GPS velocity field in the northern Adriatic region*. Geophys. Res. Lett., **32**, L16311. doi:10.1029/2005GL022947.

HANKS, T.C. & KANAMORI H. (1979) - *A moment magnitude scale*. J. Geophys. Res., **84** (B5), 2348–2350.

SERPELLONI E., ANZIDEI M., BALDI P., CASULA G. & GALVANI A. (2005) - *Crustal velocity and strain-rate fields in Italy and surrounding regions: new results from the analysis of permanent and non-permanent GPS networks*. Geophys. J. Int., **161**, 861–880.

WELLS, D.L. & COPPERSMITH K.J. (1994) - *New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement*. Bull. Seismol. Soc. Am., **84**, 4, 974–1002.